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THE SENSITIVITY OF SUGAR TECHNOLOGY PERFORMANCE TO CHANGES IN TECHNICAL AND ECONOMIC PARAMETERS[1/]

by

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INTRODUCTION

Models have been developed in two companion papers so that the performance of large scale vacuum pan and small scale open pan sulphitation (OPS) technology could be analysed in the context of a variety of African conditions (see (1) and (2) respectively). These papers present a limited amount of sensitivity analysis in the sense that certain important parameters are given different numerical values. Eight models are considered in paper (1), based on two options for length of crushing season (long, short), climate (rainfed, irrigated) and scale of production (100 tch, 200 tch where tch represents tonnes of cane per hour crushing capacity). Four models are considered in paper (2), based on long/short crushing season and 2/3 shift working (100/150 tc day).

The purpose of the present paper is to investigate how the results presented in the other papers are affected by variation in other potentially important parameters. An alternative value for the rate used to discount cash flows, and for the shadow exchange rate applied in paper (3) in an analysis of the social profitability of selected models, are considered in Chapter I. Chapters II and III contain results obtained from variation in technical parameters relating to agricultural and factory operations respectively. Finally the major conclusions are summarised in Chapter IV.

I PRIVATE AND SOCIAL PROFITABILITY

Papers (1) and (2) presented calculations of the private (or commercial) profitability of the various models in terms of their internal rates of return and net present value discounted at 10% per annum. Since all costs and benefits are measured in constant (late 1976) prices these calculations are therefore evaluated in real terms. A real discount rate of 10% per annum may appear to be on the high side, though it can be defended on two counts. Firstly there is some degree of risk attached to investment in sugar production: for one reason or another quite a number of existing sugar factories in developing countries operate below capacity for example. Secondly it is reasonable in countries where funds for investment are short to apply an exacting standard to the measurement of profitability. It is, however, advisable to consider how the models fare when the discount rate is lowered (or, alternatively, costs and revenues are allowed to rise at a given rate per annum). Annex 1 contains figures of NPV discounted at both 5% and 10% (and IRRs), for all 8 large scale and 4 small scale models, based on calculations of private costs and benefits given in terms of a set of low and of high prices. The parameter values underlying the calculations are explained in papers (1) and (2).

Most of the short season models appear, on given parameter values, to be loss making: indeed only 1 model shows a rate of return greater than 10% per annum. Further comparison in this chapter between large and small scale technologies relates to the long season situation.

In Table 1 the NPVs for the two technologies are converted to a per tonne of sugar basis, and are shown discounted at both 5% and 10% per annum. The rate of discount has a noticeable

Table 1 Net present values per tonne of sugar per annum (tsa) $

Long season	Low prices		High prices	
rainfed models	@ 5%	@ 10%	@ 5%	@ 10%
100 tch	404	-91	2012	556
200 tch	874	215	2803	1127
100 tcd	96	-141	1245	396
150 tcd	289	-11	1570	610

effect on the rank ordering at both low and high prices: in each case the 200 tch model is superior, but the relative position of the 100 tch and 150 tcd models varies - at the higher discount rate the small scale model improves its position.

Estimation of the social profitability of the long season models, as explained in (3), is based largely on the use of a shadow rate of exchange and a shadow wage rate for unskilled labour. In paper (3) the shadow exchange rate was taken as 1.5 times the official rate, whilst the shadow (unskilled) wage rate was assumed to be half the market rate. The technology comparison based on social profitability is reproduced in Annex II, together with a further set of calculations based on a shadow exchange rate of 1.25 times the official rate.

The principal difference between the results in Annex II and the corresponding private profitability results shown in Annex 1 (and Table 1 above) is the rise in the relative position of the small scale models particularly if the higher discount rate is used. It is, however, worthnoting that all the models have a higher social compared with private return; this is largely because, in the low price set, sugar is priced for private profitability at around the current world market price (CIF African ports) and so revenue at social prices rises by the full extent shown by the shadow exchange rate.

II VARIATION IN AGRICULTURAL PARAMETERS

Variations in three sets of agricultural parameters are analysed (separately) in this chapter. Case 1 considers the implication (in 200 tch models) of removing the assumption made in paper (1) of constant returns to scale in initial land clearance and in annual cultivation costs. Case 2 is based on the assumption that cane yields and unit costs of cane supply in small scale models are equal to those for the equivalent large scale models: in paper (2) it is assumed that small scale cane yields and unit costs are lower, and that annual operating cost per tonne of cane is also lower (approximately 75% of the large scale cost for the corresponding length of season). Case 3 considers the impact on costs in all rainfed models of a 50% increase in the respective cane yield (thus reducing the cane area required by one third).

Case 1 Economies/diseconomies of scale in large scale agriculture

In the 2 long season models (for 200 tch) the presence of economies of scale in land clearance and/or cane cultivation would further improve profitability relative to the 100 tch and small scale models. Analysis is therefore focussed in this situation on the implication of diseconomies of scale: the effect of a 10% increase in agricultural unit costs (excluding cane harvesting which was analysed in paper (1) on an individual case basis, and administrative overheads which are based on the presumption of economies of scale) is shown in Table 2 below, which gives the revised figures for NPV discounted at both 5% and 10%. These may be compared with the original figures shown in Annex 1. In all cases the IRR remains above 10% per annum.

The short season rainfed model (at low prices) continues to show a return below 5% p.a. even if unit costs are reduced by 10%, whilst at high prices a change of 10% either way keeps the IRR in the range 6%-9%. The corresponding irrigated model at high prices continues to earn more than 10% p.a. if unit costs rise by 10%: at low prices a change of ±10% is still associated with a return of between 6%-8%.

Table 2 Impact of a 10% change in agricultural unit costs (200 tch models) ($ million)

Model	Direction of change in costs	low prices Revised NPV @ 5%	@ 10%	high prices Revised NPV @ 5%	@ 10%
long season					
rainfed	Increase	85.5	16.9	291.5	113.2
irrigated	Increase	135.1	43.2	373.0	157.3
short season					
rainfed	Increase			14.8	-37.4
	decrease	-24.0	-41.7	47.2	-16.3
irrigated	Increase	5.1	-24.6	95.6	12.2
	decrease	17.9	-15.9		

Greater economies or diseconomies of scale than the 10% considered would thus be required if the impact is to substantially affect the overall project return.

Case 2 Equality of agricultural unit costs/cane yields

Supply of cane to OPS factories, as analysed in paper (2), is predicated on a lower input/lower output policy, compared with that adopted in the large scale situations; it is hypothesised that although cane yields are reduced by between 20% and 37% reduced expenditure on machinery and fertiliser input enables unit costs to be cut by more than this so that the overall annual operating cost per tonne of cane is 75% of the cost of large scale cane supply. As an alternative, the effect of utilising in the small scale models the same unit costs and yields as in the large scale models was investigated for both long season OPS models. The impact of this set of changes in short season models may be ignored because these models are already loss-making.

Since the cost of cane per tonne is higher under large scale costs/yields the effect of this change in parameter values is that of reducing NPVs for the OPS models. The revised NPV values are shown in Table 3. As can be seen from a comparison of these values with the corresponding figures shown in Annex 1 the effect of this change on the profitability of the models is considerable. In the more commonly occuring low price regime the IRR of even the 150 tch model falls to almost zero from 9.5% p.a., whilst in the high price regime the IRRs of both models are approximately halved. This result reflects, of course, the importance of expenditure on cane to OPS factory operating costs.

Table 3 Impact of using higher costs and yields in small scale models

Long season models	low prices Revised NPV		($ million)	high prices Revised NPV	
	@ 5%	@ 10%		@ 5%	@ 10%
100 tcd	-0.70	-0.72		0.42	-0.24
150 tcd	-0.66	-0.83		1.27	0.07

Case 3 Increase in cane yields in rainfed models.

In paper (1) cane yields per hectare in rainfed models are taken as half that used in the corresponding irrigated model. An increase of 50% in the yields in the rainfed models (raising yields to 75% of those in the irrigated situations) would mean that the required area under cane could be reduced by one third, lowering in particular both initial capital cost (land clearance and expenditure on equipment) and annual cultivation costs. The revised NPVs, given this increase in cane yield, are shown in Table 4 for all 4 large scale rainfed models, and for the 4 small scale models whose cane yields are increased by a similar percentage.

In the short season situation the small scale models remain unprofitable both relatively and, in nearly all cases, absolutely: only the 150 tcd model at high prices has an IRR approaching 5% p.a. The 100 tch large scale model is still loss making at low prices. On the other hand the profitability of the 200 tch model improves significantly if cane yield is increased: at low prices IRR is just over 5% p.a., whilst at high prices it increases to 11.2% p.a.

Table 4 Effect of increasing cane yields per hectare by 50% ($ million)

Model	low prices Revised NPV @ 5%	low prices Revised NPV @ 10%	high prices Revised NPV @ 5%	high prices Revised NPV @ 10%
1. Long season rainfed				
100 tch	41.09	7.10	140.57	49.85
200 tch	134.72	48.40	370.01	163.40
100 tcd	0.52	0.08	2.26	0.94
150 tcd	1.16	0.37	4.02	1.83
2. Short season rainfed				
100 tch	-24.26	-29.67	0.52	-24.08
200 tch	2.42	-24.65	88.51	10.96
100 tcd	-0.73	-0.63	-0.50	-0.60
150 tcd	-0.71	-0.66	-0.07	-0.42

In the long season situation both small scale models now yield more than 10% p.a. at low prices, as do both large scale models. Comparison between the technologies on a per tonne of sugar per annum basis may be made from the information contained in Table 5.

Table 5 NPV per tonne of sugar per annum for increased cane yield situations

Model	low prices @ 5%	@ 10%	($)	high prices @ 5%	@ 10%
1. Long season rainfed					
100 tch	747	129		2555	906
200 tch	1225	440		3364	1485
100 tcd	397	60		1722	715
150 tcd	591	191		2048	929
2. Short season rainfed					
100 tch	-795	-973		17	-790
200 tch	40	-404		1128	180

The ranking of the models in the long season situation is similar to that shown in Table 1 above based on the original cane yields. As before, the 150 tcd model out performs the 100 tch model at the higher discount rate.

III VARIATION IN FACTORY PARAMETERS

A key parameter representing factory operation is sugar recovery, often shown as a percentage on cane input though a superior measure is the percentage of sucrose in the cane recovered as sugar since cane sucrose content is itself a variable. In papers (1) and (2) cane sucrose content is taken as 13% and this figure is not changed here. The assumed recovery in the large scale factories - paper (1) - is 81.5% (i.e. a 10.6% sugar/cane ratio). This recovery is certainly respectable and so the alternative considered here is a 10% fall in recovery (to 73.4%). The assumed recovery in OPS units - paper (2) - is 50% (6.5% sugar/cane). Whilst an increased recovery, according to Indian experience, is feasible it is felt that the more likely alternative - associated with implanting a technology in a new environment - is reduced recovery and so both 10% and 20% decline in recovery are considered in connection with the long season models. Since the short season models are loss-making at the existing recovery rate there is less point in examining a change which must increase the loss: instead a 10% increase in recovery is considered to see if this demanding alteration in factory operation significantly improves profitability.

Annex III shows the revised NPVs for all 8 large scale models if sugar output (and revenue) is reduced by 10%: in the case of long season models the calculations relate to the less profitable (but more likely) low price regime, whereas calculations for short season models are at high prices since the low price NPVs at the existing recovery levels are already unprofitable. Comparison with the NPVs given in Annex 1 reveals that profitability when measured in terms of NPV discounted at 5% p.a. is halved in most cases. Only the 200 tch long season models now earn more than 10% p.a.

The impact of reduced sugar recovery in the long season small scale models may be determined from a comparison of Table 6 with Annex 1. The effect of a 10% drop in sugar recovery (as measured by the decline in IRRs) is more marked than in the corresponding large scale models: a 20% drop in recovery converts both models (at low prices) into loss making situations.

Table 6 Net present values associated with reduced sugar recovery in OPS units ($ million)

Model	low prices			high prices		
	NPV		IRR	NPV		IRR
	@ 5%	@ 10%	(%)	@ 5%	@ 10%	(%)
1. 10% reduction in recovery						
long season:						
100 tcd	-0.33	-0.44	0.5	0.72	0.00	10.0
150 tcd	-0.11	-0.41	4.0	1.72	0.43	14.2
2. 20% reduction in recovery						
long season:						
100 tcd	-0.78	-0.70	loss making	-0.18	-0.50	3.5
150 tcd	-0.73	-0.79	loss making	0.45	-0.33	7.5

Table 7 Net present values associated with increased sugar recovery in OPS units ($ million)

	low prices			high prices		
	NPV		IRR	NPV		IRR
	@ 5%	@ 10%	(%)	@ 5%	@ 10%	(%)
10% increase in recovery						
short season:						
100 tcd	-0.94	-0.78	loss making	-0.66	-0.77	loss making
150 tcd	-0.92	-0.87	loss making	-0.24	-0.65	3.4

Finally the effect of a 10% increase in recovery to the fortunes of the small scale units in short season situations may be determined from Table 7. Only in the 150 tcd model at high prices is this increase in performance sufficient to enable the operation to earn a positive real rate of return.

IV CONCLUSIONS

On the basis of the sensitivity analysis reported in this paper the results given in papers (1), (2) and (3) appear to be fairly robust in that certain generalisations continue to remain valid.

The models representing the short season situation (for both technologies) nearly all appear to predict loss making outcomes. Only when cane yields are improved substantially does the largest scale of production considered improve to a relatively profitable position.

Comparison of the two technologies in the long season situation shows that at low (real) rates of discount the large scale does better, but that at a higher rate of discount the 150 tcd (3 shift) model in particular improves its position. A lot, however, depends on the selected values for agricultural parameters: the superiority, especially at the social prices considered, of the small scale model is based on values which result in lower operating costs per tonne of cane supplied. Furthermore a fall of 10% in factory sugar recovery is more serious tor the small scale financial performance than for the large scale: a recovery of 45% - which is not, for the technology, a bad performance - means that the 150 tcd model earns only a 4% return at the more realistic set of prices. Even though, as is shown in Chapter I, movement from private to social costs and benefits raises the relative performance of the small scale models it would appear that sugar recovery is obviously a crucial parameter.

ANNEX I

Private net present values and internal rates of return

	low prices			high prices		
	NPV		IRR	NPV		IRR
	@ 5%	@ 10%		@ 5%	@ 10%	
	($ million)		(%)	($ million)		(%)
1. Large scale						
100 tch						
Long season rainfed	22.2	-5.0	8.7	110.7	30.6	15.0
irrigated	45.9	7.2	11.7	148.9	53.8	17.3
Short season rainfed	-42.5	-41.5	<0	-28.0	-42.9	1.3
irrigated	-18.6	-26.3	0.9	12.1	-18.1	6.5
200 tch						
Long season rainfed	96.2	23.7	13.4	308.4	124.0	20.2
irrigated	142.0	48.0	16.1	384.1	164.9	22.2
Short season rainfed	-34.4	-48.5	0.7	31.0	-26.8	7.1
irrigated	11.5	-20.2	6.4	105.8	19.1	12.0
2. Small scale						
100 tcd						
Long season rainfed	0.13	-0.19	6.5	1.63	0.52	15.4
Short season rainfed	-1.16	-0.93	<0	-1.18	-1.07	<0
150 tcd						
Long season rainfed	0.57	-0.02	9.5	3.09	1.20	18.9
Short season rainfed	-1.34	-1.12	<0	-1.08	-1.15	<0

ANNEX II

Measures of social profitability for long season rainfed models

	Large scale		Small scale	
	100 tch	200 tch	100 tcd	150 tcd
1. Shadow exchange rate 1.5 x official rate				
NPV @ 5%	93.5	243.2	2.35	3.97
NPV ÷ tsa	1701	2211	1791	2020
NPV @ 10%	29.8	97.5	1.01	1.84
NPV ÷ tsa	541	886	768	935
IRR (%)	15.5	20.1	22.1	26.3
2. Shadow exchange rate 1.25 x official rate				
NPV @ 5%	59.9	173.7	1.57	2.79
NPV ÷ tsa	1089	1579	1198	1420
NPV @ 10%	13.6	63.0	0.62	1.23
NPV ÷ tsa	247	573	473	626
IRR (%)	12.9	17.6	19.5	23.7

Notes: all NPV figures in $ million (low prices)
all NPV per tsa in $

ANNEX III

Net present values associated with reduced sugar recovery
($ million)

	NPV @ 5%	NPV @ 10%	IRR (%)
1. Long season models (at low prices)			
<u>100 tch</u>			
rainfed	2.2	-16.2	5.4
irrigated	25.9	-4.1	9.0
<u>200 tch</u>			
rainfed	56.2	1.4	10.2
irrigated	102.0	25.6	13.5
2. Short season models (at high prices)			
<u>100 tch</u>			
rainfed	-50.9	-56.2	loss making
irrigated	-10.8	-31.5	3.3
<u>200 tch</u>			
rainfed	-14.9	-53.6	4.0
irrigated	59.9	-7.6	9.2

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